

# **Crusoe Power Management:**

## **Cutting x86 Operating Power Through LongRun**

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# Overview

- ◆ **Key Challenges for Mobile Computing**

- ◆ “Portability” (weight) and “Ease of Use” (battery life)
- ◆ Power consumption is the key limiting factor

- ◆ **Solution - Crusoe Processor**

- ◆ Full compatibility with x86 power management model
- ◆ Significantly lower power

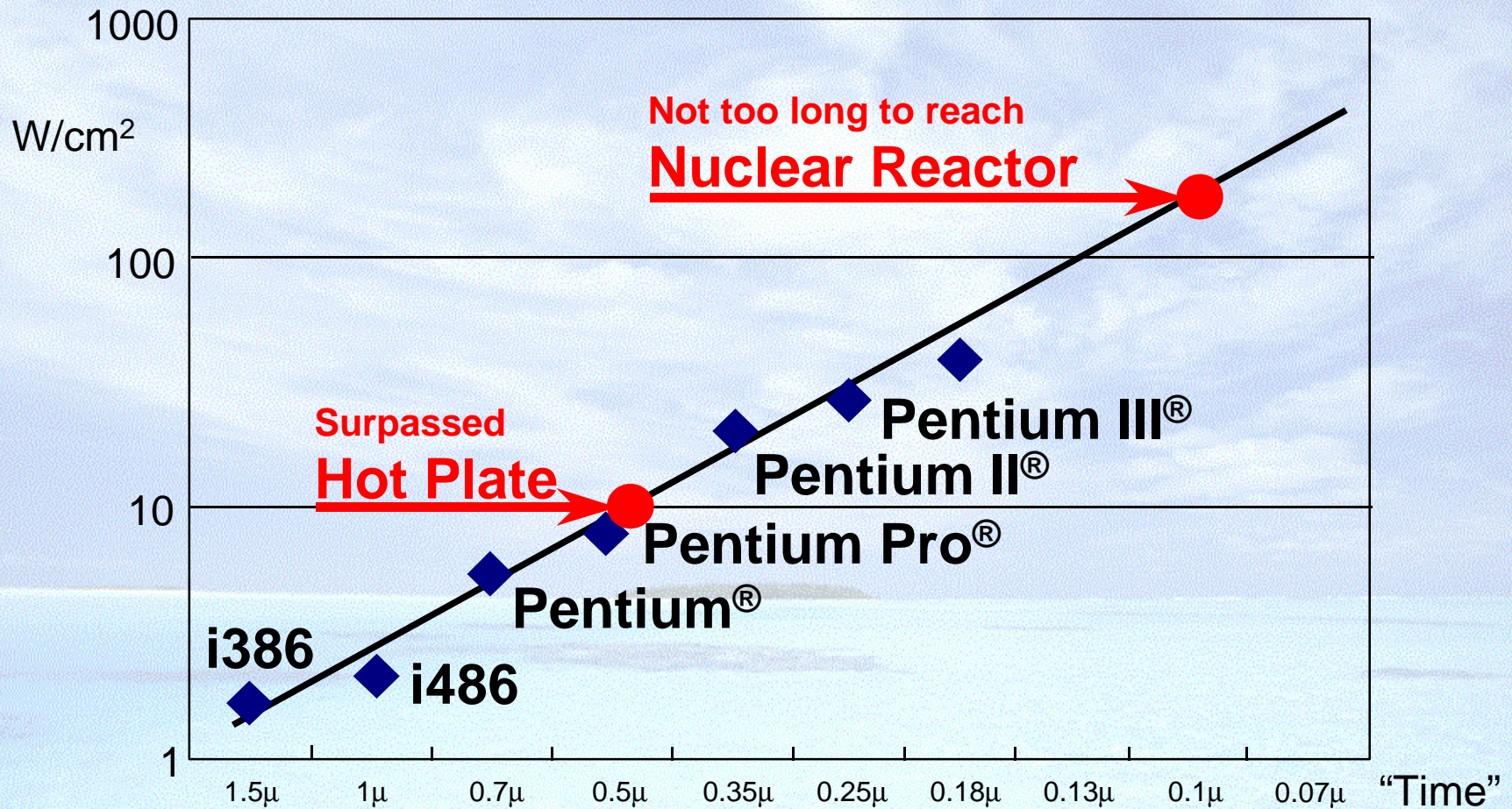
- ◆ **LongRun**

- ◆ Transmeta’s new invention to drive power savings
  - Adaptive Power Control (performance on demand)
  - Advanced Thermal Control (thermal budget expansion)



# Power Density

## The Fundamental Problem



Source: Fred Pollack, Intel. New Microprocessor Challenges in the Coming Generations of CMOS Technologies, Micro32



# X86 Power Management States

## A Quick Primer

### ACPI Definition Mobile x86 Power States

Advanced Communication and  
Power Interface Specification

### Mobile x86 Solution

#### Processor

650 / 500 MHz  
1.6 / 1.35 V

<b>Normal (C0)</b>	<ul style="list-style-type: none"> <li>The CPU is actively executing instructions.</li> </ul>	14.0 / 8.0	W
<b>AutoHALT (C1)</b>	<ul style="list-style-type: none"> <li>CPU executes a low power instruction (x86: <b>HLT</b>).</li> </ul>	1.7 / 1.1	W
<b>Quick Start (C2)</b>	<ul style="list-style-type: none"> <li>CPU kills internal clocks (driven by South Bridge via STPCLK#).</li> <li>CPU maintains cache coherence (caches must be snooping).</li> </ul>	1.3 / 0.8	W
<b>Deep Sleep (C3)</b>	<ul style="list-style-type: none"> <li>South Bridge kills external clock input to the CPU.</li> <li>Maximum power savings w/o losing CPU context.</li> <li>System enforces cache coherence (caches don't need to snoop).</li> </ul>	0.5 / 0.3	W



# The Solution - Increase Efficiency

$$P_{power} = C_{capacitance} \times V_{oltage}^2 \times F_{requency}$$

- ◆ **Transmeta Innovation - Code Morphing Software (CMS)**
- ◆ **Effect - Replace Millions of Logic Transistors with Software**
  - ◆ ... and transistors translate into capacitance
- ◆ **Benefit - Significantly Reduces Power Consumption of x86 Power States**

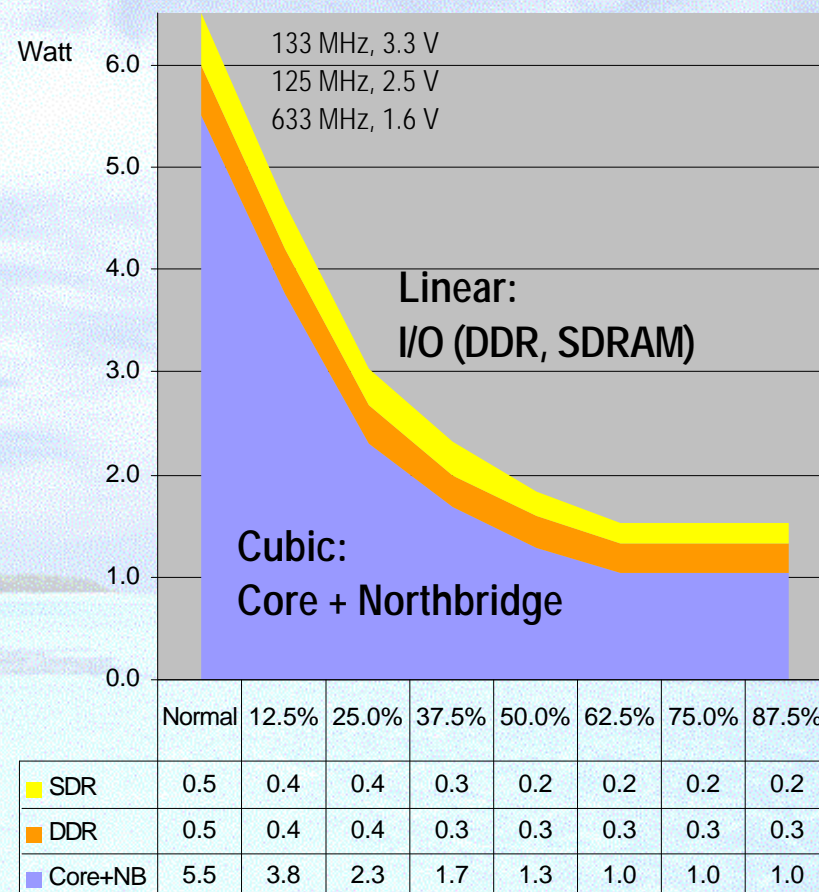


# LongRun Adaptive Power Control

Maximize Battery Life With Performance on Demand

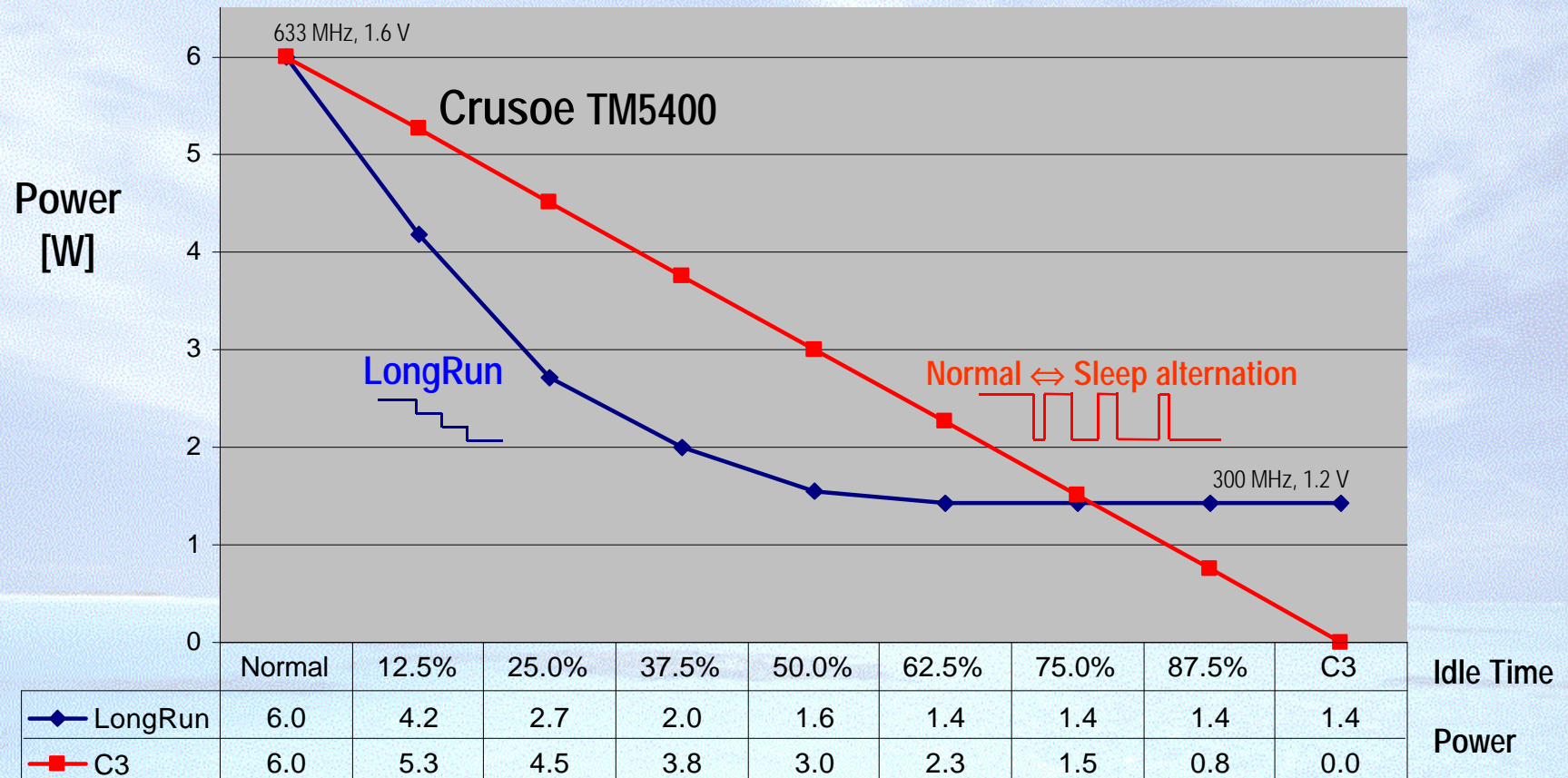
$$Power = c \times v^2 \times f$$

- ◆ Dynamically adapt both frequency and voltage to performance demands
- ◆ Mechanisms in hardware
  - Fully programmable
- ◆ Policies in CMS
  - ◆ Adapt  $f$  to demand
  - ◆ Reduce  $v$  proportionally
    - Cubic power savings!





# LongRun Adaptive Power Control vs. Traditional Power Management



## Notes

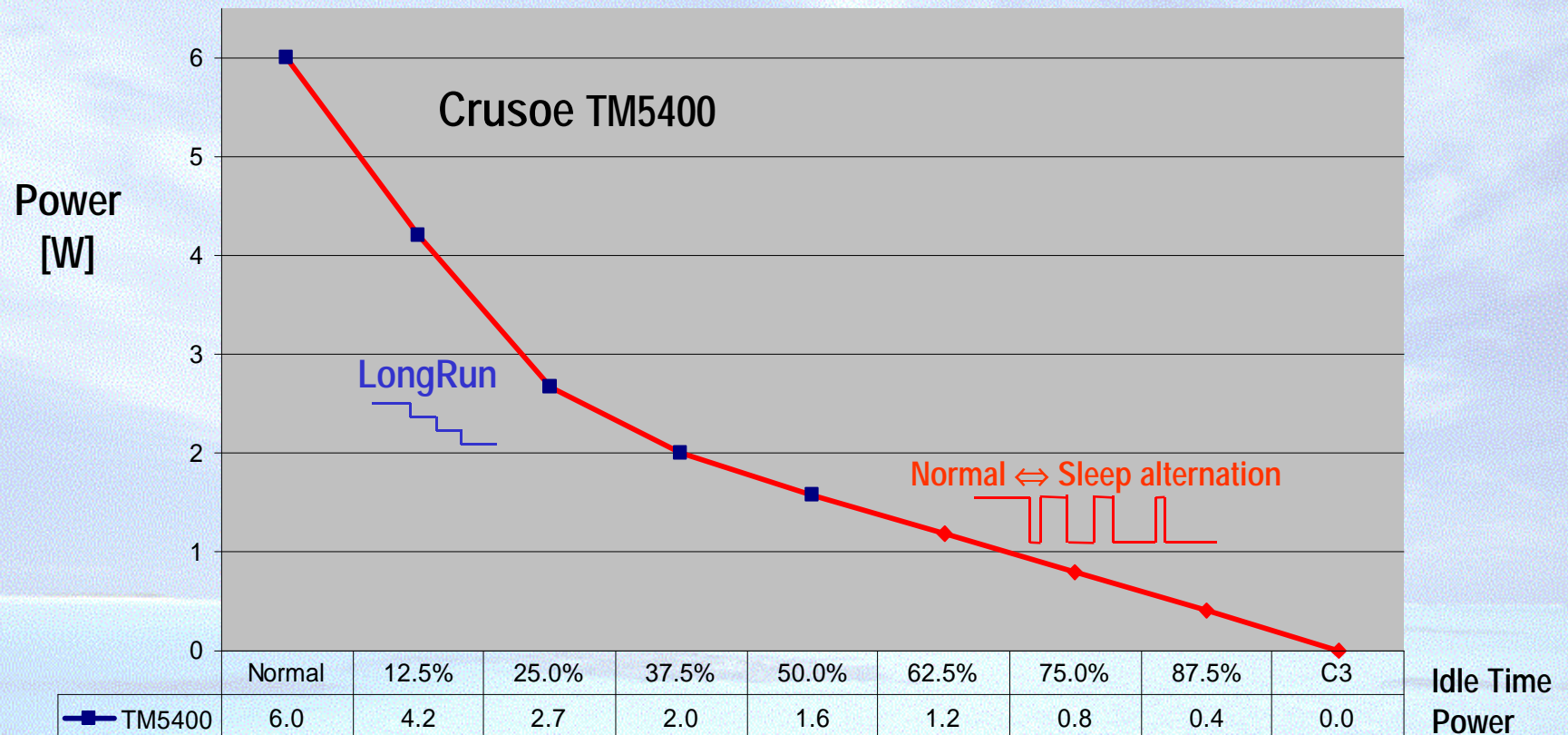
<sup>1</sup> Power numbers include Northbridge

<sup>2</sup> DDR-only configuration



# LongRun Adaptive Power Control

## Crusoe Power Profile



### Notes

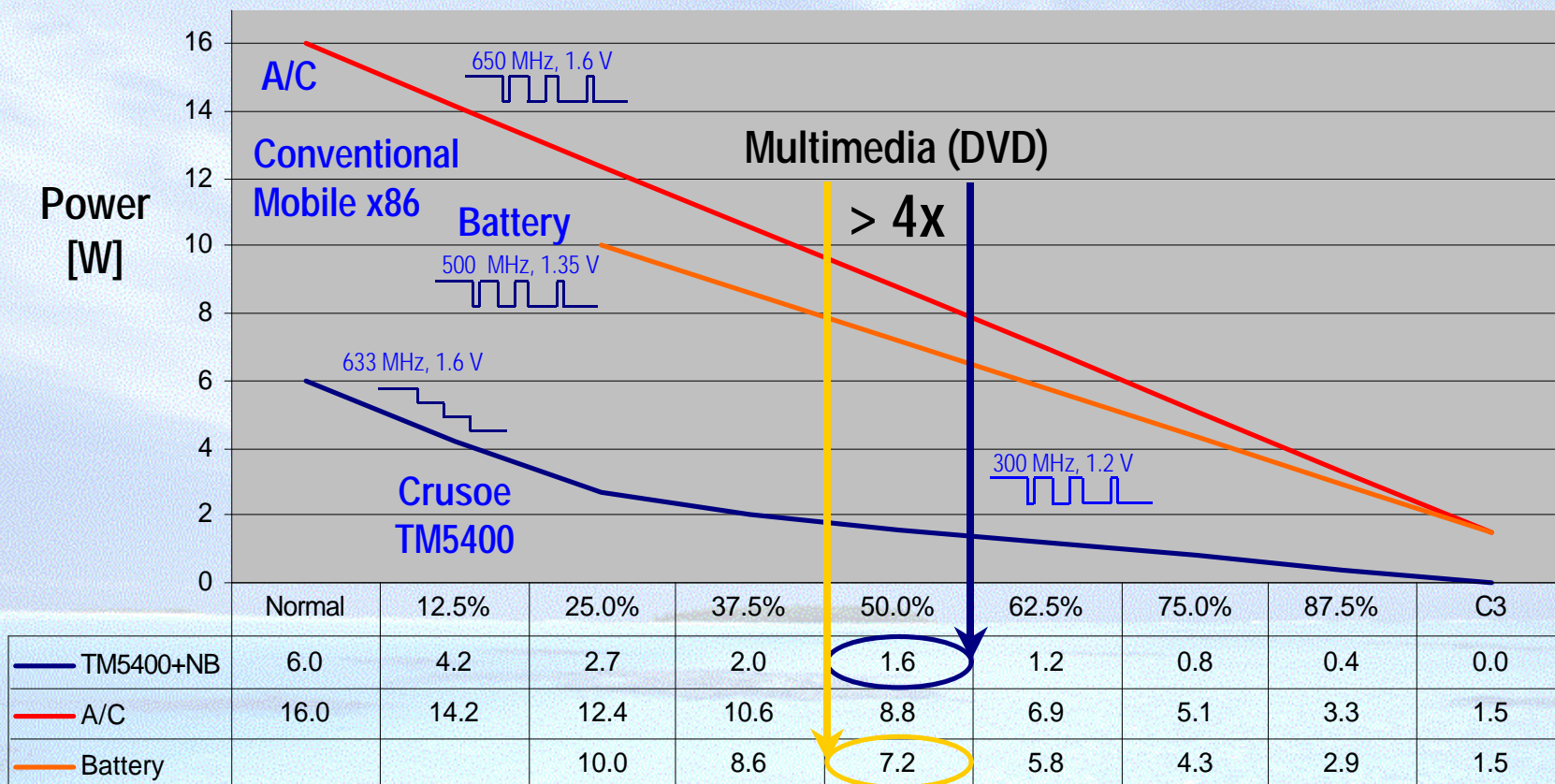
<sup>1</sup> Power numbers include Northbridge

<sup>2</sup> DDR-only configuration



# The LongRun Effect

## Power Profiles



### Notes

<sup>1</sup> Power numbers include Northbridge

<sup>2</sup> DDR-only configuration



# System Architecture

## Standard Applications

No changes required



Closed loop

## Standard Operating System

No changes required

Closed loop

## Standard BIOS

No changes required

Closed loop

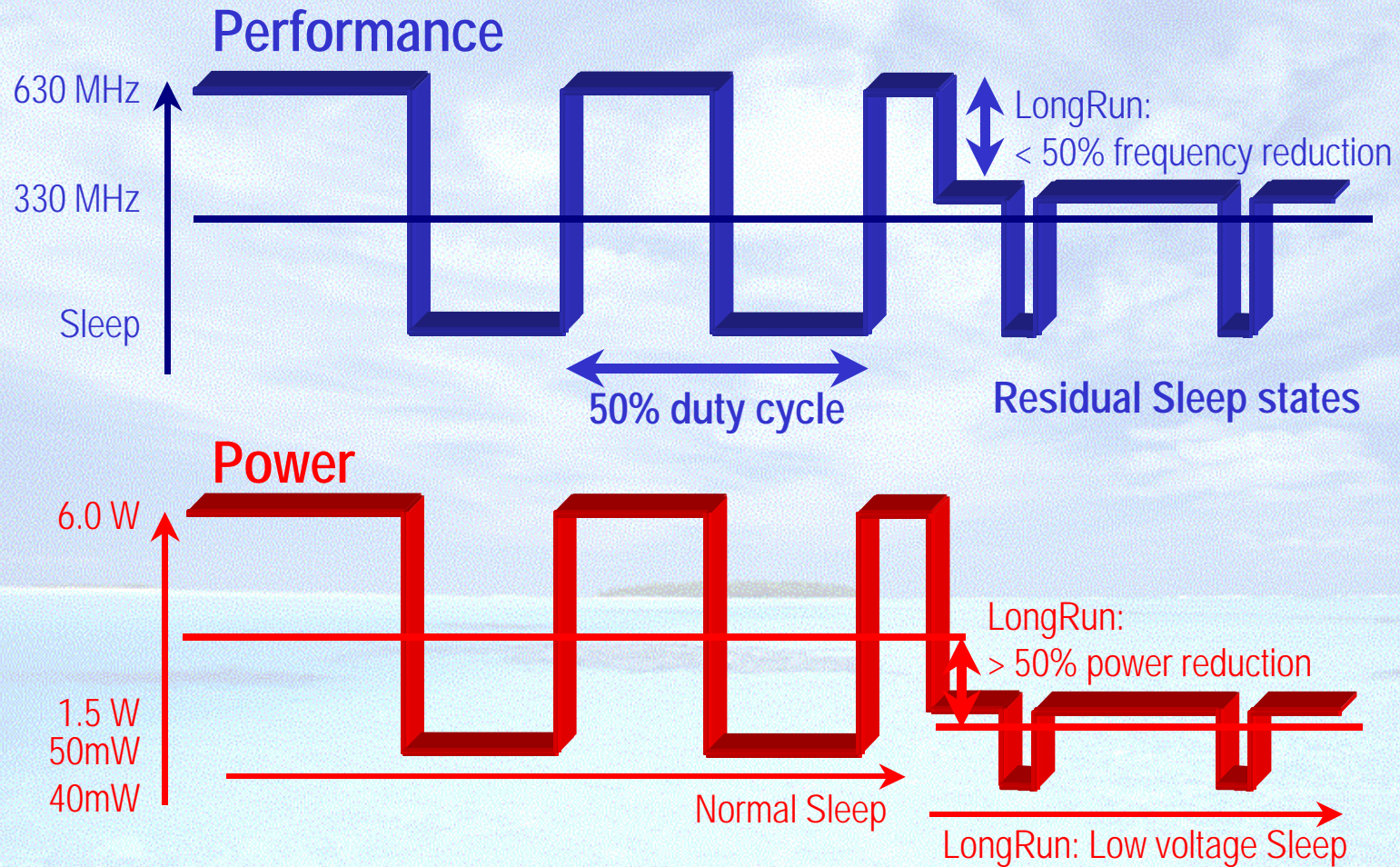
## Crusoe TM5400 processor featuring Transmeta LongRun technology

Code Morphing software monitors system activity and dynamically adapts LongRun performance levels



# Performance on Demand

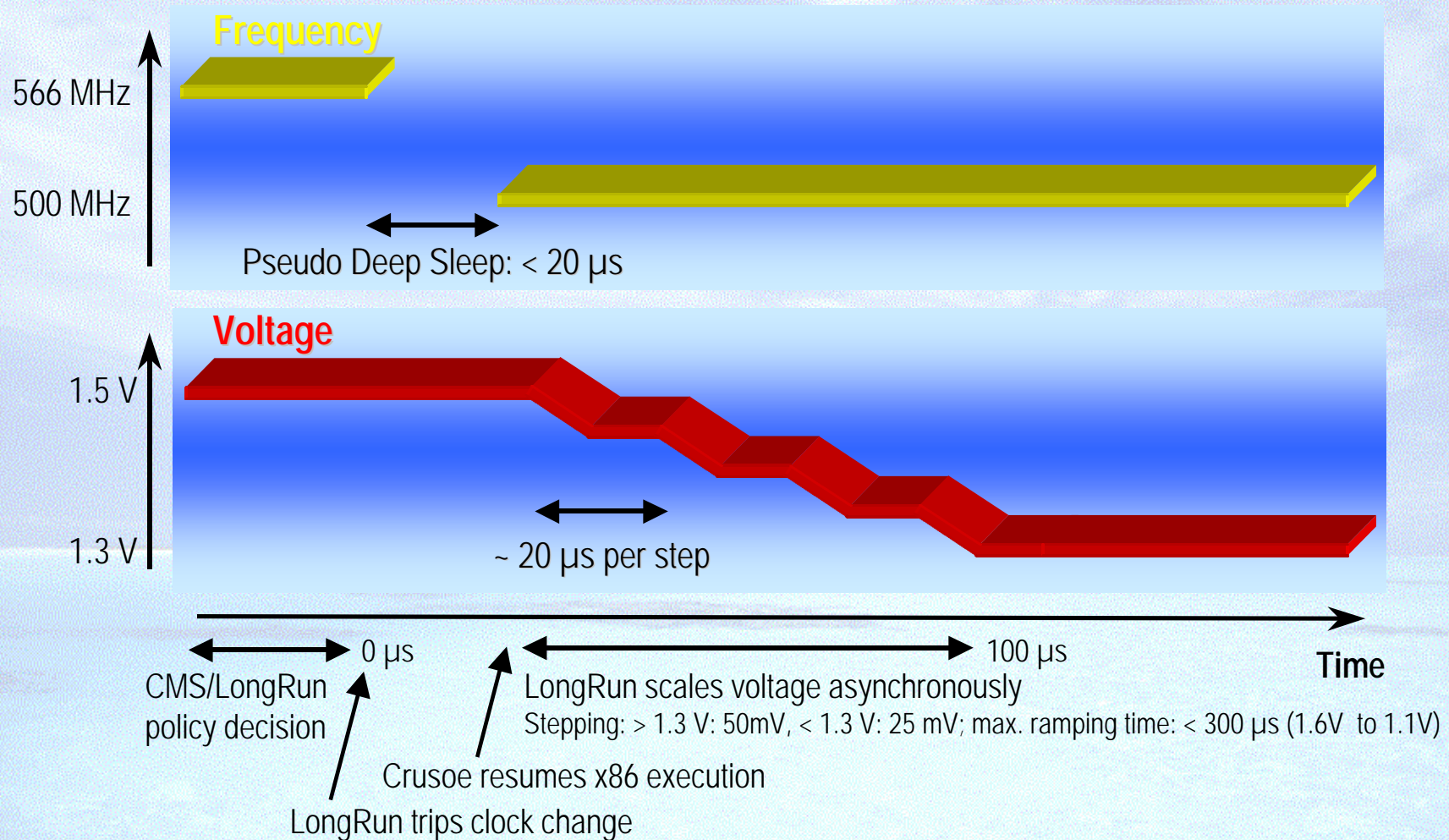
Duty Cycle      Effective Performance Level





# Transition Dynamics

## Fast Frequency/Voltage Scaling





# Transition Details

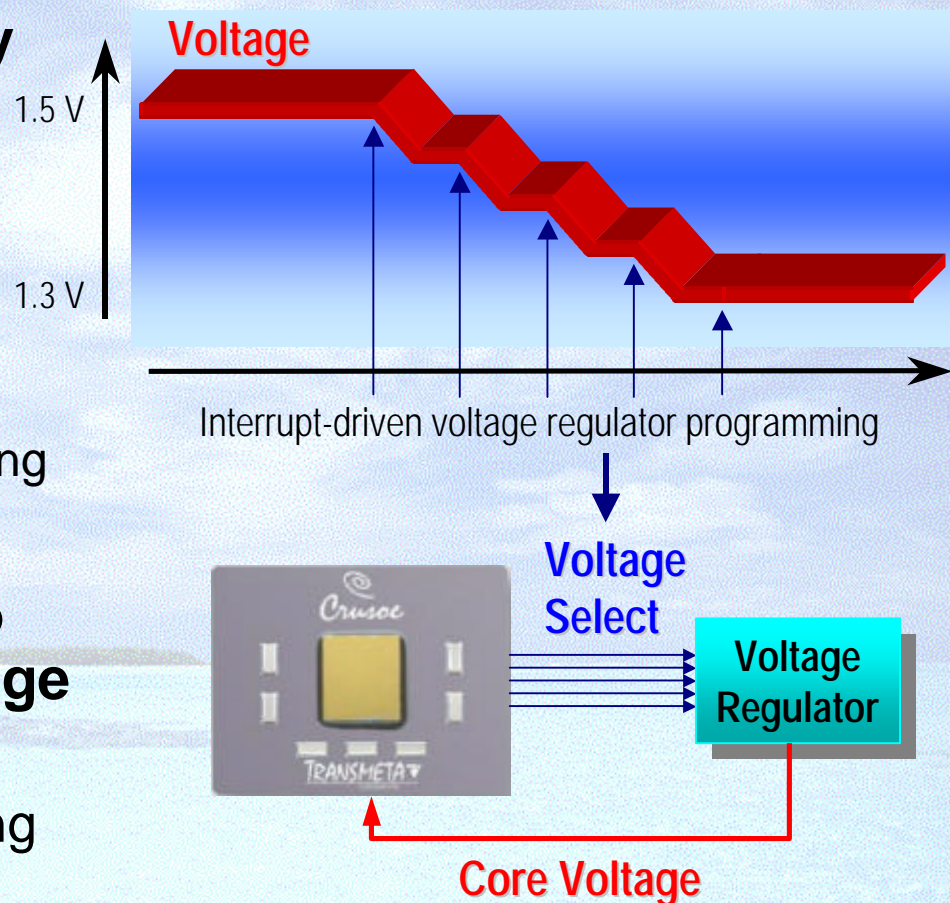
## Voltage Scaling

- ◆ **TM5400 Core Voltage is Fully Under Software Control**

- ◆ CMS directly controls voltage regulator pins (via internal processor register)
- ◆ OEM configurable
  - CPU output pin/voltage mapping
  - Voltage settling interval

- ◆ **CMS Schedules Interrupts to Asynchronously Ramp Voltage**

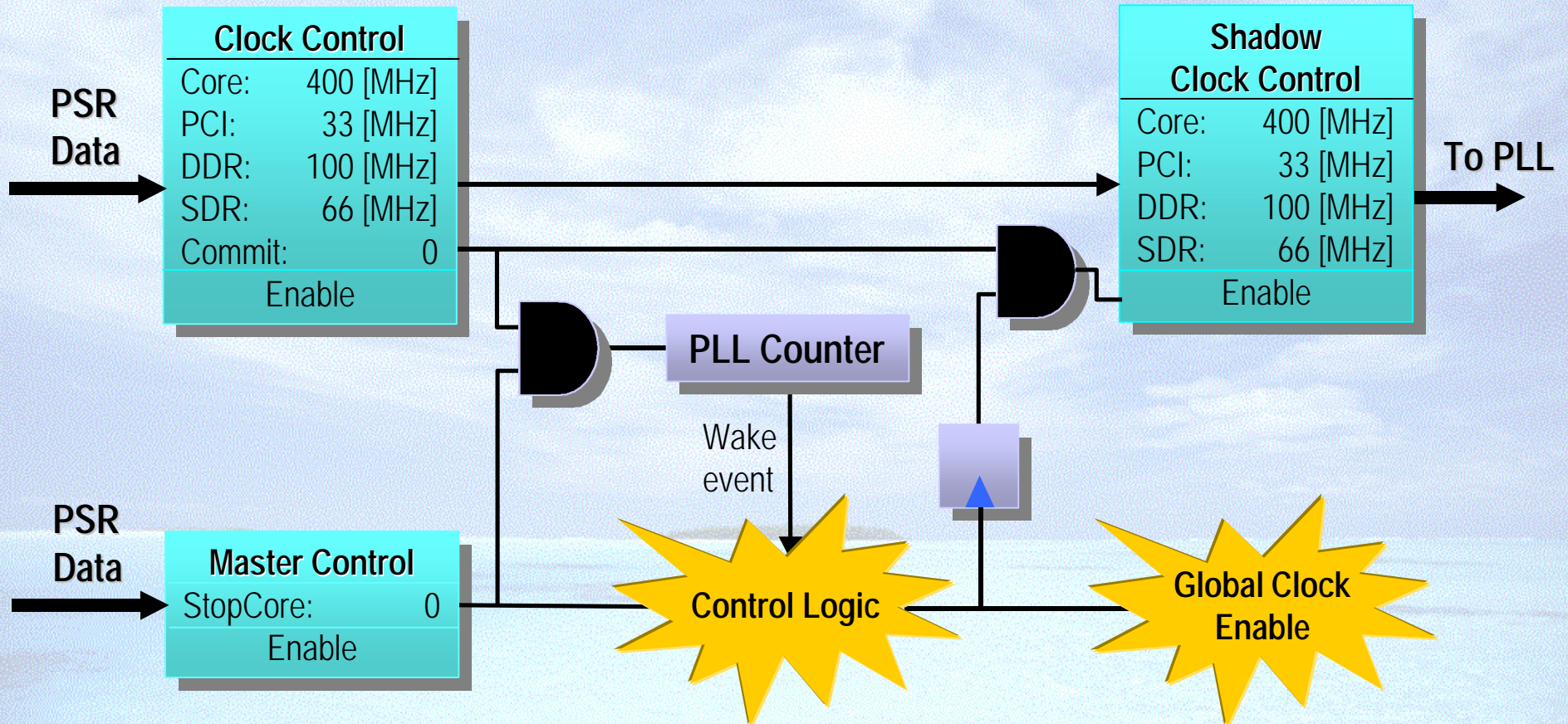
- ◆ Allows sustained x86 forward progress during voltage ramping





# Transition Details

## Frequency Scaling - Establish/commit control





# Programming Interface

## Processor and Northbridge

### Adaptive Power Control

CPU interface

#### CPUID 8086 0001h

EDX:0	LongRun supported
ECX	Nominal core frequency

#### CPUID 8086 0007h

EAX	Current core frequency
EBX	Current core voltage
ECX	Current performance percentage

#### MSR 8086 8010h

EDX	Upper boundary (% of max. performance)
EAX	Lower boundary (% of max. performance)

### Advanced Thermal Control

Northbridge interface

#### Function 0, Register A8h

Bit 4	Thermal Management enabled
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Bit 1:3 Power reduction level

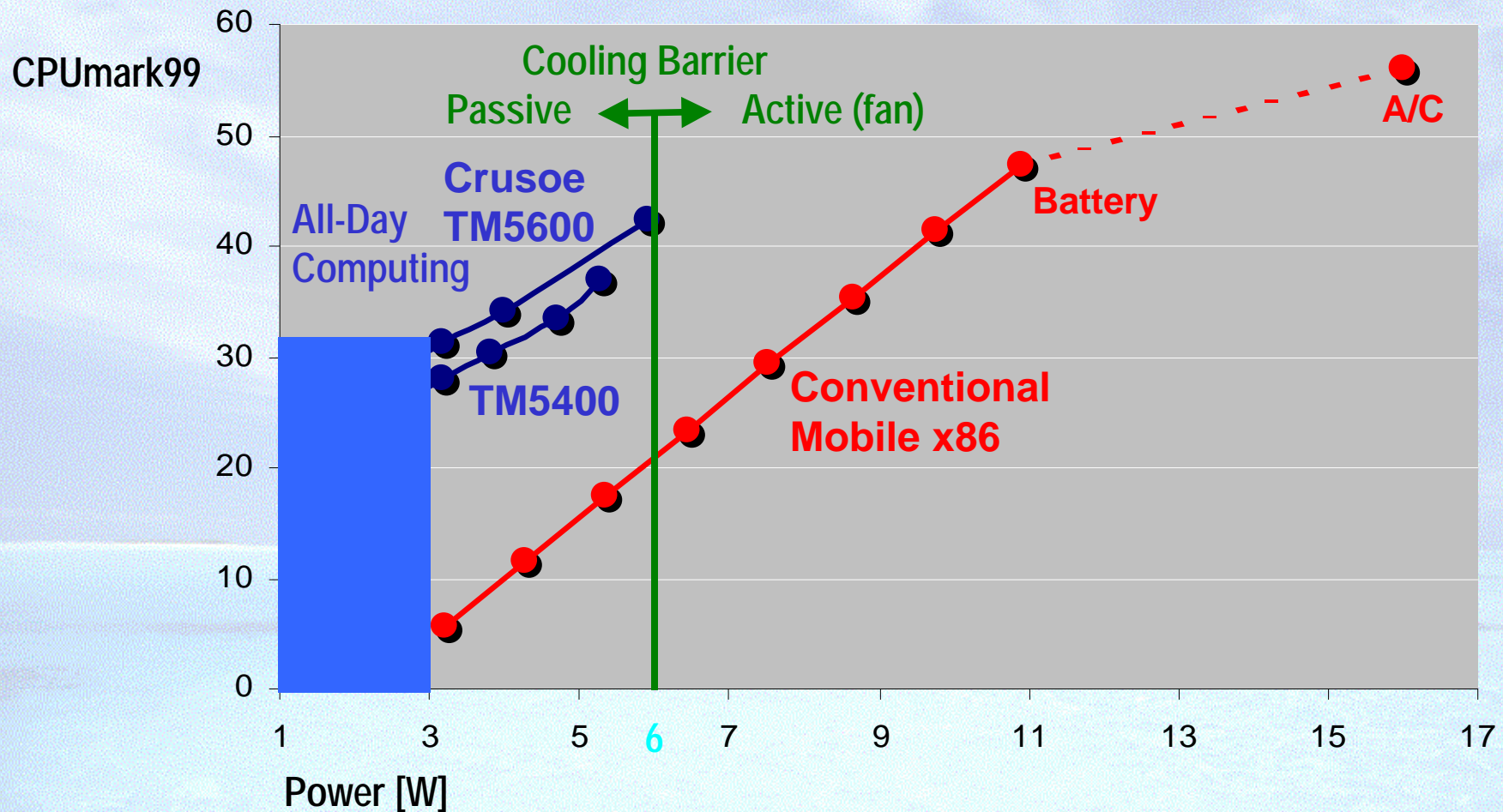
Bits	Mode
000	Reserved
001	Reserved
010	75.0%
011	62.5%
100	50.0%
101	37.5%
110	25.0%
111	12.5%

Bit 0	LongRun supported
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# Energy Efficiency

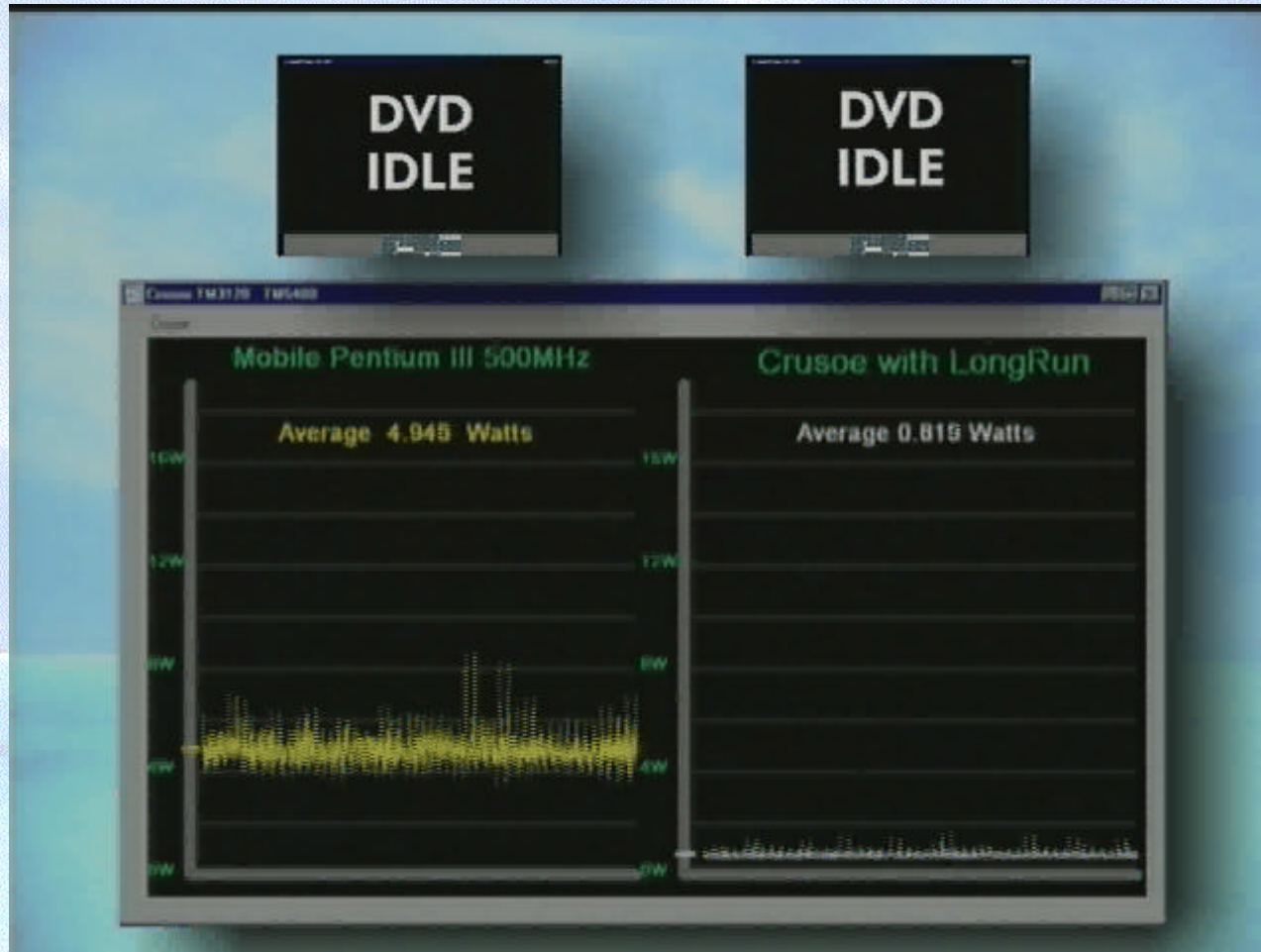
## Superior Performance in Small Form Factors





# The LongRun Advantage

## DVD Playback - Performance on Demand





# Power Comparison

## Substantial Power Reduction, Delivered by Crusoe

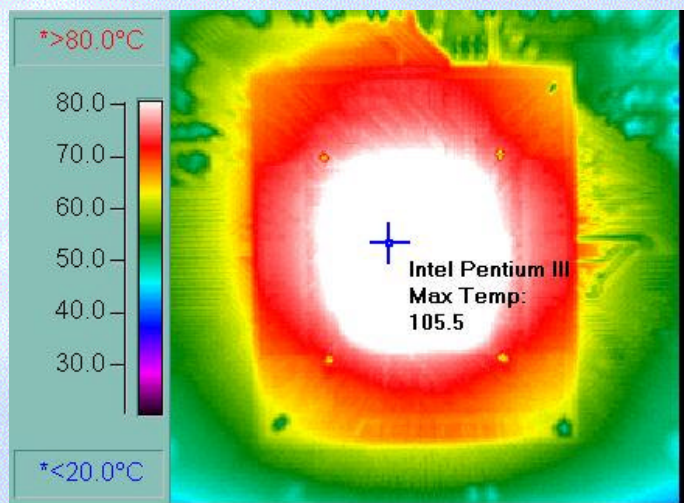
		Conventional Mobile x86 Solution			Crusoe TM5400 Integrated North Bridge		
		Processor 650 / 500 MHz 1.6 / 1.35 V	North Bridge 3.3 V	Total 650 / 500 MHz 1.6 / 1.35 V	LongRun 633 300 MHz 1.6 1.2 V		
Normal (C0)		14.0 / 8.0	2.0	16.0 / 10.0	6.5	1.5	Watts
AutoHALT (C1)		1.7 / 1.1	2.0	3.7 / 3.1	0.9	0.3	Watts
Quick Start (C2)		1.3 / 0.8	2.0	3.3 / 2.8	0.6	0.2	Watts
Deep Sleep (C3)		0.5 / 0.3	~1.0	1.5 / 1.3	0.05	0.05	Watts

- ◆ Crusoe plays Soft-DVD at the same power that conventional mobile x86 processors use in Deep Sleep!



# The LongRun Advantage

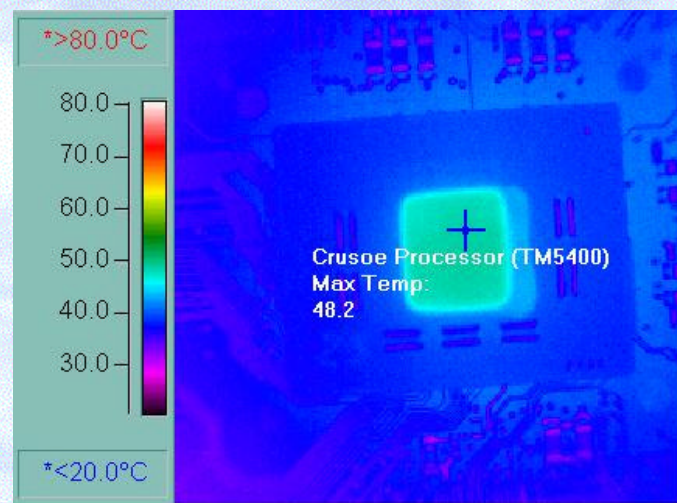
## DVD Playback - Thermal Comparison



Conventional Mobile x86  
Processor

**105.5° C      221.9° F**

Active thermal solution required  
(Fan or overload protection)



Crusoe TM5400 Processor  
with LongRun

**48.2° C      118.8° F**

Passive thermal solution  
(No fan or overload protection)



# Summary

- ◆ **Crusoe Supports the x86 Power Management Model with Significantly Reduced Power Consumption**
  - ◆ Sleep: 4× (C1) - 30× (C3) power savings
- ◆ **Crusoe Leverages Code Morphing Software to Drive Performance on Demand - LongRun**
  - ◆ Normal: 2× - 10× power savings
- ◆ **Crusoe Leverages LongRun to Expand the Thermal Budget**
- ◆ **Crusoe's Innovative Low-Power Technology Portfolio**
  - ◆ Enables a whole new class of battery-powered devices
  - ◆ The full PC and Internet experience - Anywhere and Anytime





# Crusoe